REMARKS

By this Amendment, Claims 1, 22 and 24 have been amended. Claims 1-24 are pending in the application. Reconsideration and allowance of the application are respectfully requested in light of the above amendments and the following remarks.

Rejection Under 35 U.S.C. § 112, ¶2

Claim 24 stands rejected under 35 U.S.C. § 112, ¶2.

Claim 24 has been amended to recite the features of "the plasma etch reactor has a showerhead electrode and a bottom electrode on which the substrate is supported, the bottom electrode ... the first frequency" to provide antecedent basis for the recited bottom electrode and showerhead electrode.

Withdrawal of the rejection is respectfully requested.

Rejections Under 35 U.S.C. § 103

A. Claims 1-3, 9-17 and 19-21 stand rejected under 35 U.S.C. § 103(a) over U.S. Patent Application Publication No. 2003/0162407 to Maex et al. ("Maex") in view of U.S. Patent No. 6,485,988 to Ma et al. ("Ma"). The reasons for the rejection are stated on pages 3-4 of the Official Action. The rejection is respectfully traversed.

Claim 1 has been amended to recite a process for etching a low-k dielectric layer with selectivity to an overlying mask layer, which comprises "supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a doped glass low-k material and an overlying mask layer; supplying an oxygen-free etching gas to the chamber ..., the etching gas comprising at least one nitrogen reactant, at least one fluorocarbon reactant and optional carrier gas, ... the fluorocarbon reactant flow rate is less than the nitrogen reactant flow rate; etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma

while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5, wherein the plasma etch reactor comprises a dual frequency parallel plate plasma reactor having a showerhead electrode and a bottom electrode on which the substrate is supported" (emphasis added). Support for the amendments to Claim 1 is provided, for example, in the paragraph bridging pages 10-11 and at page 18, lines 15-17 of the present specification.

The Official Action asserts that Maex teaches etching .25 micron features through a low-k dielectric layer with an oxygen-free plasma that comprises a fluorocarbon (e.g., CF_2H_2) and nitrogen; that Maex teaches a N_2: fluorocarbon flow ratio of at least 2:1 and that Maex teaches the plasma may also include an inert gas, such as Ar. The Official Action also asserts that Maex teaches the layer underlying the low-k material can be silicon carbide, silicon nitride or titanium nitride. Finally, the Official Action asserts that Maex teaches applying the method to a dual damascene process.

The Official Action acknowledges that Maex does not teach an etching selectivity with respect to overlying and underlying layers of at least 5:1, but asserts that "this [selectivity] is a result that naturally flows from the claimed process and therefore this result is be [sic] also expected to [be] achieved by Maex." The Official Action also acknowledges that Maex fails to disclose using a dual-frequency parallel plate reactor including a showerhead electrode and a bottom electrode on which the substrate is supported. In addition, the Official Action acknowledges that Maex does not teach etching features with a 5:1 aspect ratio.

However, the Official Action asserts that Ma teaches etching a low-k dielectric material with fluorocarbon etchants, such as those taught by Maex. It is further asserted in the Official Action that Ma teaches that one can expect to achieve the desired results in such a process, regardless of the etching platform or apparatus that is used to carry out the process.

The Official Action further asserts that it would have been obvious to use a dual-frequency parallel plate plasma apparatus to perform the method of Maex, that it would have been obvious to use a substrate temperature of 20°C-50°C and that it would have been obvious to etch features with a 5:1 aspect ratio. Applicants respectfully disagree with these assertions.

Applicants respectfully submit that the combination of Maex and Ma fails to suggest the claimed process for etching a low-k dielectric layer with selectivity to an overlying mask layer. In contrast to the process recited in Claim 1, Maex is directed specifically to methods for etching <u>organic</u> insulating layers, such as organic insulating layers composed of the organic low-k materials described at paragraph [0038] of Maex. Maex does not suggest any method for etching a doped glass low-k material, as recited in Claim 1. In contrast, Maex discloses that "[t]he <u>organic materials are of particular interest</u> because they feature simplified processing, excellent gap-fill and planarization" (paragraph [0004], emphasis added). Thus, Maex teaches away from etching a low-k dielectric layer of a doped glass low-k material, as recited in Claim 1.

Moreover, the Official Action acknowledges that Maex does not disclose or suggest any particular etch rate selectivity of the etching rate of the low-k dielectric layer of organic low-k material to the etching rate of the mask layer, much less a

selectivity of the etching rate of a low-k dielectric layer of a doped glass low-k material to the etching rate of an overlying mask layer of at least about 5, as recited in Claim 1.

Ma fails to cure the deficiencies of Maex regarding the process for etching a low-k dielectric layer of a doped glass low-k material, as recited in Claim 1. Particularly, Ma discloses a method of forming a conductive contact to a top electrode of a ferroelectric capacitor. Ma discloses that interlevel dielectric layers 112, 134 and 160 may be made of multiple different materials, including a low dielectric constant material (column 13, lines 19-25). Ma also discloses that the interlevel dielectric layer 408 shown in Figure 4a may be made of multiple different materials, including a low dielectric constant material (column 22, lines 31-41).

Ma discloses numerous combinations of etch gases for etching layers 402, 404, 406, 408 and/or 410 (column 22, lines 17-30). Ma discloses numerous combinations of etch gases that contain one or more oxygen-containing gases. However, Ma does not suggest picking and choosing gases from among the numerous combinations of etch gases to result in an oxygen-free etching gas that comprises "at least one nitrogen reactant, at least one fluorocarbon reactant and optional carrier gas, ... the fluorocarbon reactant flow rate is less than the nitrogen reactant flow rate," as recited in Claim 1.

Moreover, Ma does not suggest using the etching gas recited in Claim 1 for etching a low-k dielectric material of a doped glass low-k material with a selectivity of at least about 5 with respect to an overlying mask layer. For example, each of the preferred etch gas chemistries disclosed at column 24, lines 1-4 of Ma contain oxygen, while, in contrast, Claim 1 recites an oxygen-free etch gas. Also, Table 2 at

column 24 of Ma discloses etching of the layer 408 with an etch gas chemistry that does not include at least one nitrogen reactant, while, in contrast, the etch gas recited in Claim 1 includes at least one nitrogen reactant.

In contrast to Maex and Ma, the present inventors determined that an etch gas chemistry that contains at least one nitrogen reactant and at least one fluorocarbon reactant, but is free of oxygen, can provide an "etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5," as recited in Claim 1. The inventors also determined that, in contrast, etch gas chemistries that contain at least one nitrogen reactant, at least one fluorocarbon reactant and oxygen may not provide an etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer that is less than 5. Particularly, Table 4 at page 24 of present specification shows the low-k dielectric (CORAL) etch gas flow rates for different runs, where each of the gas chemistries includes C_4F_8, CF_2H_2 and N_2. The gas chemistries used for runs 2, 3, 5 and 8 are oxygen-free, as recited in Claim 1. In contrast, the gas chemistries for runs 4 and 7, for example, include oxygen.

Table 5 at page 24 of the present specification shows etch rates for the low-k dielectric layer of CORAL, a doped glass low-k material, and an overlying mask (photoresist) layer. The etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the photoresist layer was less than 5 for runs 4 and 7. In contrast, in runs 2, 3, 5 and 8 where an oxygen-free etch gas was used, etch rate selectivity values of 18.0, 5.6, 9.6 and 12.6, respectively, were achieved. These test results demonstrate that an oxygen-free etch gas including at least one nitrogen reactant and at least one fluorocarbon reactant can unexpectedly achieve an etch

rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the overlying mask layer of at least 5, whereas etch gases that contain at least one nitrogen reactant, at least one fluorocarbon reactant and oxygen achieve lower selectivity values that may be significantly lower than 5.

Because Maex teaches away from providing a low-k dielectric layer of a doped glass low-k material, the cited references provide no suggestion or motivation to modify Maex's process of etching organic low-k layers to achieve the combination of features recited in Claim 1. Moreover, the unexpected results achieved by the process recited in Claim 1 rebut any alleged *prima facie* case of obviousness. Therefore, the process recited in Claim 1 is patentable over the combination of Maex and Ma.

Claims 2, 3, 9-17 and 19-21 depend from Claim 1 and thus are also patentable over the combination of Maex and Ma for at least the same reasons as those stated above for Claim 1. Furthermore, these dependent claims recite additional combinations of features that further patentably distinguish the claimed process over the cited references. For example, Claim 2 recites the features of "the low-k dielectric layer is above an underlying silicon carbide layer, the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon carbide layer," and Claim 3 recites the features of "the low-k dielectric layer is above an underlying silicon nitride layer, the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon nitride layer." Neither Maex nor Ma discloses or suggests the combinations of features recited in Claims 2 and 3. Claim 17 recites the features of "the openings are formed [in the low-k dielectric layer of a doped glass low-k material] with an aspect ratio of at least 5:1."

Neither Maex nor Ma discloses or suggests the combination of features recited in Claim 17.

Therefore, withdrawal of the rejection is respectfully requested.

B. Claims 4, 8, 18 and 22-24 stand rejected under 35 U.S.C. § 103(a) over Maex and Ma and further in view of U.S. Patent No. 6,455,411 to Jiang et al. ("Jiang"). The reasons for the rejection are stated on pages 4-5 of the Official Action. The rejection is respectfully traversed.

The Official Action acknowledges that Maex does not teach the use of "heavier fluorocarbon" etchants, but asserts that Jiang teaches that certain fluorocarbons are functionally equivalent in their capacity as etchants of low-k dielectric materials. It is also asserted in the Official Action that it would have been obvious to use C_4F_8 or C_5F_8 in place of, or in addition to, the CH_2F_2 of Maex's etchant. Applicants respectfully disagree with these assertions.

Claims 4, 8 and 18 depend from Claim 1. Jiang fails to cure the deficiencies of Maex and Ma with respect to the process recited in Claim 1. Namely, Jiang discloses a dual damascene process for low-k dielectric materials. Referring to Figures 2A and 2B, Jiang discloses etching a structure including, in successive order, semiconductor body 100, first interconnect layer 102, etch-stop layer 104, via level dielectric layer (ILD) 106, trench level dielectric (IMD) 108 and capping layer 110. Jiang discloses that the ILD 106 and IMD 108 are of organo-silicate glass (OSG). Jiang discloses that the via etch chemistry for etching vias 112 comprises C_5F_8, N_2 and CO, i.e., an oxygen-containing etch chemistry (see column 3, lines 24-26, and Figure 2A). Jiang further discloses trench etch gas chemistries for etching IMD 108 (column 3, line 38 – colulmn 4, line 20). However, Jiang fails to suggest

modifying Maex's method to result in the features of "the semiconductor substrate having a low-k dielectric layer of a doped glass low-k material and an overlying mask layer; supplying an oxygen-free etching gas to the chamber ..., the etching gas comprising at least one nitrogen reactant, at least one fluorocarbon reactant and optional carrier gas, ... the fluorocarbon reactant flow rate is less than the nitrogen reactant flow rate; etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5" (emphasis added). Accordingly, the combination of Maex, Ma and Jiang fails to suggest the combinations of features recited in Claims 4, 8 and 18, which are thus patentable.

Claim 22 has been amended to recite a process for etching a low-k dielectric layer with selectivity to an overlying mask layer, which comprises "supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a doped glass low-k material and an overlying mask layer; supplying an etching gas ... comprising C_4F_8, CF_2H_2, N_2 and optionally Ar, the C_4F_8, CF_2H_2 and N_2 being supplied to the chamber at flow rates such that the total C_4F_8 and CF_2H_2 flow rate is less than the N_2 flow rate and the flow rate ratio of the fluorocarbon reactant to the nitrogen reactant is 30% or less.; and etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5" (emphasis added). Maex teaches away from etching a low-k dielectric layer of a doped glass low-k dielectric material. Each of Maex, Ma

and Jiang fails to disclose or suggest that the recited selectivity of the etching rate of a low-k dielectric layer to the etching rate of a mask layer of at least about 5 is achieved for any combination of a low-k dielectric material and an overlying mask. Thus, the combination of features recited in Claim 22 also is patentable over the combination of Maex, Ma and Jiang.

The combinations of features recited in Claims 23 and 24 also are patentable for at least the same reasons that Claim 22 is patentable.

Therefore, withdrawal of the rejection is respectfully requested.

C. Claims 1-6, 9-16 and 18 stand rejected under 35 U.S.C. § 103(a) over Jiang in view of Ma. The reasons for the rejection are stated on pages 5-6 of the Official Action. The rejection is respectfully traversed.

The Official Action asserts that Jiang teaches plasma etching a low-k dielectric layer using an etchant comprising a fluorocarbon and a greater amount of nitrogen. It is further asserted in the Official Action that Jiang teaches etching low-k dielectric layers (106 and 108) through an overlying patterned layer of SiN (capping layer 110). It is further asserted that Jiang teaches etching a layer of low-k dielectric that is disposed upon an underlying layer of SiC (104). It is also asserted in the Official Action that Jiang teaches etching a layer of low-k dielectric material that overlies a barrier layer comprising TaN. It is acknowledged in the Official Action that Jiang does not teach the type of plasma reactor in which the process is carried out.

The Official Action asserts that Ma teaches etching a low-k dielectric material with fluorocarbon etchants, such as those taught by Jiang. It is also asserted that Ma teaches that one can expect to achieve the desired results in such a process, regardless of the etching platform, or apparatus, that one uses to carry out the

process. It is asserted in the Office Action that it would have been obvious to use a dual-frequency parallel plate plasma apparatus to carry out the method of Jiang because this type of apparatus is among the most widely used plasma apparatus and given the teaching of Ma.

For reasons stated above, Jiang and Ma fail to suggest the combination of features recited in Claim 1, including at least the features of "supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a doped glass low-k material and an overlying mask layer; supplying an oxygen-free etching gas to the chamber and energizing the etching gas into a plasma state, the etching gas comprising at least one nitrogen reactant, at least one fluorocarbon reactant and optional carrier gas, the fluorocarbon reactant and nitrogen reactant being supplied to the chamber at flow rates such that the fluorocarbon reactant flow rate is less than the nitrogen reactant flow rate; etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5, wherein the plasma etch reactor comprises a dual frequency parallel plate plasma reactor having a showerhead electrode and a bottom electrode on which the substrate is supported" (emphasis added). Accordingly, Claim 1 is patentable over the combination of Jiang and Ma.

Dependent Claims 2-6, 9-16 and 18 are thus also patentable for at least the same reasons that Claim 1 is patentable.

Therefore, withdrawal of the rejection is respectfully requested.

Conclusion

Therefore, allowance of the application is respectfully requested. Should the Examiner desire to discuss this application, the undersigned attorney can be reached at the telephone number given below.

Respectfully submitted,

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